ELECTRO-MECHANICAL CONTINUOUSLY VARIABLE TRANSMISSION

FIELD

This invention relates to a drive system useful as a vehicle propulsion system or stationary equipment drive, combining mechanical and electric power systems.

BACKGROUND

Electric drive systems have been commonly used for large vehicles or stationary equipment. However, as the output/input speed ratio increases, the electric motor & generator no longer operate at their optimum operating speeds. This reduces the overall efficiency of the drive at the upper half of the drive's operating range. This problem may be overcome by having multiple gear settings to keep the motors and generators operating at or near their optimum speeds, but the complexity of the resulting transmission negates the benefits of using an electric drive.

An alternative to an electric drive system is a mechanically driven system. However, conventional mechanical drive systems are limited to discrete gear ratios, which do not allow for infinite speed ratios as found in electric drives. A great deal of power management

between the engine and the transmission at all output speeds is necessary for transmission effectiveness. A purely mechanical drive is inadequate to ensure the efficient use of the engine's available power due to the discrete speed ratios, while a purely electric drive has inherently lower efficiency at higher operational speeds.

With the increasing costs of fuel and more stringent emissions requirements, there is a need for more efficient drive systems for large and small vehicles, as well as stationary equipment, to replace traditional electric and mechanical drive systems.

It is an object of this invention to provide a more efficient drive system for large and small vehicles and stationary equipment by combining electric and mechanical power systems. It is a further object of this invention to provide a transmission system for optimizing use of combined drive systems.

SUMMARY

The invention comprises an electro-mechanical continuously variable transmission (EMCVT) that uses a planetary gear system to provide a combination of electric

and mechanical power for a vehicle or for stationary equipment. The EMCVT includes a clutch and brake system that allows power from an energy storage unit to be combined with the main power input (typically an engine) to provide a torque output greater than that available from the main power input alone.

The EMCVT may also include a range splitter system to expand the operating parameters of the vehicle or stationary equipment.

The EMCVT may further include a regenerative steering system to control power distribution between the two ends of the main output shaft.

The EMCVT may additionally include a lockup brake coupled to the electric branch input, operative to lock out the electric branch and force all power through the mechanical branch when the transmission output is operating at a pre-selected percentage of its maximum speed.

While the EMCVT can provide output in both forward and reverse direction, it may optionally include a reversing gear system coupled at either the main power input or the main output shaft. The reversing gear system allows the

EMCVT to provide an output in the reverse direction while the components in the electrical and mechanical operate in the same fashion as the forward direction.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention itself, both as to organization and method of operation, as well as additional objects and advantages thereof, will become readily apparent from the following detailed description when read in connection n with the accompanying drawings:

Figure 1 shows a block diagram of an EMCVT with two outputs, a parallel shaft configuration, and an SRC planetary gear set;

Figure 2 shows a simplified diagram of a three-planet planetary gear set;

Figure 3 shows a block diagram of an EMCVT with two outputs, a coaxial shaft configuration and an SRC planetary gear set;

Figure 4 shows a block diagram of an EMCVT with one output, a coaxial shaft configuration and an SRC planetary gear set;

Figure 5 shows a block diagram of the EMCVT of Figure 1 with a two-speed range doubler;

Figure 6 shows a block diagram of the EMCVT of Figure 1 with a regenerative steering system;

Figure 7 shows a block diagram of the EMCVT of Figure 1 with a two-speed range doubler and a regenerative steering system;

Figure 8 shows a table listing the engine, brake and clutch configurations for various operating modes of the EMCVT; and

Figure 9 shows a block diagram of the EMCVT of Figure 1 with a geared reverser coupled to the power input.

DETAILED DESCRIPTION OF THE INVENTION

The electro-mechanical continuously variable transmission (EMCVT) shown in **Figure 1** is designed to split power from an input **40** between an electric drive branch **20**, using an electric generator **22** and an electric motor **24**, and a parallel mechanical drive branch **21**, using shafts and/or gears, recombining the power from each branch into a single main output **26**.

A simple planetary gear set **10**, as shown in more detail in **Figur 2**, consisting of sun gear **12**, planet gear(s) **14**, carrier **16**, and ring gear **18** is used to split power from input **40**, derived from an internal combustion engine or other primary power source (not shown), between the electrical drive branch **20** and the mechanical drive branch **21**.

Although six planetary element combinations are possible, the preferred embodiment is an SRC configuration i.e. sun gear **12** connected to the electrical branch **20**, ring gear **18** connected to the mechanical branch **21** and the carrier **16** connected to the input **40** (see **Figure 1**).

The electrical drive branch consists of a primary generator **22**, a primary motor **24**, and is connected to an energy storage system **100**. The energy storage system consists of a battery bank **130**, an optional capacitor bank **140**, inverters **110** and **120** and a controller **150**. Power flow is normally directed between the generator **22** and the motor **24** by a controller **150**. The inverters **110** and **120** match the differing power characteristics (current, current type, voltage and frequency) of the generator **22**, motor **24**,

battery bank **130** and capacitor bank **140**. The battery bank **130** may be charged in one of 2 ways: by absorbing power from the input **40** or by absorbing energy from braking.

The combiner gear set **28** couples the electrical branch **20** to the main output shaft **26**. The combiner gear set **28** is shown as a pair of spur gears, however, a planetary gear set (as shown in **Figures 3** and **4**) may also be used for more advanced power control systems. Power from the electrical branch **20** is combined with power from the mechanical branch **21** at this point.

The mechanical drive branch **21** is shown as a simple shaft directly connecting one of the elements of the planetary gear set **10** to the main output shaft **26**, but may be a more extensive assembly of shafts and gears to accommodate the physical layout requirements of the transmission.

Several brakes and clutches shown in **Figure 1** may be used to control various aspects of the power distribution between the mechanical **21** and electrical **20** branches. The lockup brake **80** selectively connects/disconnects the electrical output element (sun gear **12** in the SRC

configuration) of the planetary gear set **10** to ground, preventing that element of the planetary gear set **10** from transmitting any power.

The generator input clutch **160** selectively connects/disconnects the electrical output element of the planetary gear set **10** to the primary generator **22**. Engaging the input clutch **160** to connect the electrical output element (sun gear **12** in the SRC configuration) of planetary gear set **10** also allows the primary generator **22** to absorb power from the planetary gear set **10**.

The generator output clutch **170** selectively connects/disconnects the primary generator **22** to/from the combiner gear set **28**. This allows the generator **22** to supplement power provided by the primary motor **24** to the combiner gear set **28**.

The mechanical drive clutch **90** selectively connects/disconnects the mechanical output (ring gear **18** in the SRC configuration) of the planetary gear set **10** to/from the mechanical branch.

The split speed clutch **180** selectively locks/unlocks two elements of the planetary gear set **10** together

preventing any differential speed between the elements. During certain operating modes, it is desirable to lock all three elements (sun **12**, ring **18**, carrier **16**) of the planetary gear set **10** together. In **Figure 1**, the split speed clutch **180** is located between the carrier 16 and sun gear **12**. The clutch **180** may alternatively be located between the sun gear **12** and ring gear **18** or between the ring gear **18** and carrier **16**.

Energizing the split speed clutch **180** locks the carrier **16** and sun gear **12** together. Due to the nature of the planetary gear set **10**, the ring gear **18** is forced to turn at the same speed as the other two elements. A reaction torque is now only required at two of the three elements and the planetary gear set **10** is now acting as a rigid coupling between three input/outputs. The ability to lock the planetary gear set **10** in this manner is required for "Burst" mode as well as the engine starting modes described below.

<u>Energy Storage System</u>

Incorporating an energy storage system **100** in the electrical **20** branch can increase the performance and

efficiency of the transmission in two ways: energy normally lost during braking by conventional mechanical methods may be recovered for later use; and energy stored in the system **100** may be applied to the transmission output **26** at the same time as peak engine power is applied resulting in a higher power output than is possible with the engine alone.

During periods of low power demand at the main output **26**, some of the power drawn from the engine at input **40** may be directed to the battery bank **130** by the controller **150** using generator **22** to convert it into electrical power. Engine output power will have to be slightly increased to accommodate the extra power demand. The specific requirements for charging are covered in the discussion of the various operating modes.

During braking operations, the energy normally absorbed by conventional brakes may be directed back through the transmission to the engine (engine braking). The motor **24** functions as a generator and the generator **22** functions as a motor. Power that normally flows back to the generator **22** may be diverted to the battery bank **130** by the controller **150**. Under heavy or prolonged braking

conditions, the battery charge rate or overall capacity may be exceeded. Under these conditions, the excess power can be directed back to the engine or to a capacitor bank **140**, which has a much higher charging rate than the battery bank **130**. When braking demands cease, energy stored in the capacitor bank **140** may be used to charge the battery bank **130**. The various braking procedures are discussed in more detail below.

Power from the battery bank **130** may be used to supplement the power drawn from the engine at input **40** during periods of high demand. Consequently, the engine may be reduced to a more economical size to meet average operating conditions while relatively high performance peaks may still be obtained. This "boost" mode is discussed under forward operating modes below.

Layout

The EMCVT core is shown in, but not limited to, three basic layouts.

Figure 1 shows a parallel shaft arrangement with two outputs. The planetary gear set **10** is arranged coaxially around the main output shaft **26**, and the primary generator

22 and primary motor **24** are arranged parallel shaft to the main output shaft **26**. The input **40** uses a separate parallel shaft. The input **40** may alternatively use a shaft perpendicular to the main output shaft **26**, driving the input to the planetary gear set **10** through a bevel gear set (not shown). The parallel shaft arrangement is suited but not limited to an application where transmission width is an issue but major components may be stacked vertically or front to back. An example would be the drive for a tracked vehicle with limited width between tracks.

Figure 3 shows a coaxial shaft arrangement with two outputs and parallel shaft input. Here the components of the electrical **20** and mechanical **21** branches are arranged coaxially around the main output shaft **26**, except for energy storage system **100**, which is located separately. Combiner gear set **28** is a planetary gear set. The input **40** uses a shaft parallel to the main output shaft **26**. The input may alternatively use a shaft perpendicular to the main output shaft **26**, driving the input to the planetary gear set **10** through a bevel gear set. The coaxial, dual output arrangement is suited but not limited to an application requiring a relatively compact transmission

with little or no width limitation. An example would be a front wheel drive vehicle utilizing a transverse engine.

Figure 4 shows a coaxial shaft arrangement with one output and a coaxial input shaft. The components are arranged are in **Figure 3**, except that power input **40** is set at one end of main output shaft **26**, leaving only one end for output. This arrangement creates a long, narrow inline power train suited to long narrow drive bays. An example of this would be a conventional front engine, rear wheel drive vehicle.

<u>Operation</u>

Referring to **Figure 1** and **Figure 8**, several modes of operation are possible but five forward power modes, three reverse power modes and four braking modes are deemed useful. During a typical duty cycle, the transmission may be switched several times between the available modes to optimize efficiency and output power.

The operating modes of the transmission are listed in the table in **Figure 8**, along with engine, clutch and brake setting for each mode. These modes can be divided into

four categories: Forward, Reverse, Braking and Engine Starting.

Forward Operation:

Five modes of operation are available for forward rotation of the output i.e. forward vehicle motion. Not all modes need be available for any given application of the EMCVT.

Forward Full Electrical Mode:

In forward full electrical mode, the generator output clutch **170** is engaged. The primary generator **22** and primary motor **24** both function as motors and draw energy stored in the capacitor and battery banks **140**, **130**. No engine power is drawn from the input **40** and the primary power source (engine) may be allowed to idle or may be shut off completely. This mode is best used for short periods of high torque output such as during initial startup and high acceleration to a higher speed. Electrical mode also drains the capacitor bank **140** and battery bank **130**.

Forward Full Electrical + Engine Mode ("Burst" mode):

In "Burst" mode, the engine is in operation and mechanical drive clutch **90**, generator output clutch **170** and

split speed clutch **180** are all engaged. The primary generator **22** and primary motor **24** both function as motors and draw energy stored in the capacitor and battery banks **140, 130**. Engine power is drawn from input **40** and is delivered directly to the output shaft **26** through the planetary gear set **10** (with all elements locked by split speed clutch **180**) and mechanical drive clutch **90**. This mode is used to provide a maximum torque output for a short duration (burst) that exceeds that available from the main input **40** alone. Burst mode also drains the capacitor bank **140** and battery bank **130**.

Forward Economy Mode:

In Economy mode, none of the clutches are engaged. Only the primary motor **24** is used to power the main output shaft **26**. Energy is drawn from capacitor and battery banks **140, 130** to power motor **24**. No engine power is drawn from the input **40** and the primary power source (engine) may be allowed to idle or shut off completely for maximum fuel savings. The duration of operation for this mode is determined by the capacities of battery and capacitor bank **130, 140**. This mode is used to maximize fuel economy and/or to operate with minimum noise levels.

Forward Parallel Mode:

In parallel mode, the mechanical drive clutch **90** and generator input clutch **160** are engaged, and the engine is in operation. Power provided by the primary power source is drawn from the input **40** of the EMCVT and is split between the mechanical branch **21** and the electrical branch **20**. Since the planetary gear set **10** divides input torque according to a fixed ratio, power is split according to the speed of the particular element connected to each branch. Initially, the mechanical branch **21** does not turn as it is directly connected to the output shaft **26**. The primary generator **22** is forced to turn near its upper speed limit. The primary generator **22** produces electrical power that is directed by the controller to the primary motor **24**. The primary motor **24** then forces the output shaft **26** to turn. Adjusting the current/frequency characteristics of the motor **24** and generator **22** varies the effective gear ratio of the electrical branch **20**. At the lower half of the EMCVT speed band, power is transferred primarily electrically.

As the output speed increases, so does the speed of the mechanical branch **21**. Since input speed is being held

constant, the speed of the primary generator **22** must decrease. To do this, the effective gear ratio of the electrical branch **20** is altered by adjusting the current/frequency characteristics to reduce the power supplied by the primary motor **24** to the combiner gear set **28**. The net result is that more of the input power is being delivered mechanically and less electrically.

Finally, near the upper end of the EMCVT's speed range, the primary generator **22** barely turns, producing very low power levels in the electrical branch **20** with power from input **40** being delivered to output **26** almost exclusively through the mechanical branch **21**. Ideally, the primary generator **22** stops turning completely with only a holding torque generated against the corresponding planetary gear set **10** element. "Full Mechanical" mode, below, discusses how this unique stage of EMCVT operation can be achieved.

During intermediate stages of the RPM range, a small amount of electrical power (approximately 10%) can be diverted from the primary motor **24** and used to charge the battery bank **130**. The stored energy is then available at a later time for other modes of operation as described above.

Parallel mode is the primary mode of operation for the majority of EMCVT applications and is designed for periods of medium power demands over varying output speed, i.e. conventional driving. Parallel mode allows the use of a smaller, more efficient primary power source (engine) to suit cruise power as well as reducing the size of the battery/capacitor bank compared to a conventional (non-parallel) hybrid internal combustion/electric drive.

Forward Full Mechanical Mode:

Mechanical Mode is an extension of the parallel mode. As stated above, in parallel mode, at the upper end of the EMCVT's speed range, the primary generator **22** barely turns and ideally should stop. Limitations of current motor/generator technology makes it impractical to hold the generator **22** at zero speed. In order to run the EMCVT in full mechanical mode, a lockup brake **80** is introduced to provide the torque reaction necessary against the planetary gear set **10** by locking the electric output element (sun gear **12** in SRC configurations) to ground, typically the outer casing of the transmission. As a result, the generator **22** is locked out and the mechanical branch **21** is responsible for supplying all the power to the output shaft

26. Otherwise, operation is the same as Parallel mode. Mechanical mode is designed for use when the EMCVT is operating near or at maximum speed for a period of time.

Reverse Operation:

Three modes of operation are available for reverse rotation of the output. Equivalents to the forward Burst mode and Mechanical mode are not available for reverse operation. Should the full range of forward modes be required for reverse operation, an optional geared reverse may be installed at the input **40** of the transmission. See "Optional Components" after this section.

Reverse Full Electrical Mode:

The generator output clutch **170** is engaged as described for forward Electrical mode above. The difference is that the generator **22** and motor **24** are run in reverse to effect reverse output. Electrical mode is used for short periods of reverse operation where high torque is required.

Reverse Economy Mode:

In Economy mode all clutches are disengaged as described for forward Economy mode above. The primary

motor **24** is run in reverse to effect reverse output. Economy mode can be used for short periods of reverse operation with low power demands.

Reverse Parallel Mode:

In Parallel mode the mechanical drive clutch **90** and generator input clutch **160** are engaged as described for Forward Parallel mode above. Power provided by the primary power source (not shown) is drawn from the input **40** of the EMCVT and is split between the mechanical branch **21** and the electrical branch **20**. In order to effect reverse output speed during Parallel mode, the primary motor **24** is used to reverse the main output shaft **26**. The element of the planetary gear set **10** connected to the mechanical branch **21** (hence, the main output shaft **26**) is forced to turn opposite to its normal (Forward mode) direction. The elements of the planetary gear set **10** connected to the input **40** and electrical branch **20** (primary generator **22**) turn in the same direction as in Forward mode. Since the torque applied to each of elements of the planetary gear set **10** is in the same direction as in Forward mode, the resultant negative power flow in the mechanical branch **21** must be compensated for by increasing the power flow in the

electrical branch **20**. For the same output speed in reverse in Parallel mode, the electrical branch **20** must pass a greater amount of power than in forward. The components of the electrical branch **20** must either be increased in capacity or reverse must be limited to slow to medium speeds. During this mode, charging of the battery/capacitor banks **130**, **140** may take place.

Parallel mode is the primary operating mode for the reverse direction and may be used for extended periods of reverse operation with medium power demands over varying slow to medium output speed or when little or no energy has been stored in the battery/capacitor banks **130**, **140**.

Braking Operation:

A significant advantage of the EMCVT over conventional transmissions is the use of regenerative braking - the recovery and storage of braking energy for later use. Conventional braking (retarding) systems reduce speed by removing kinetic energy from the vehicle or machine and dissipating it as heat. These conventional systems may consist of a mechanical, hydraulic or electromagnetic braking system. The EMCVT removes kinetic energy and stores it as electrical/chemical energy in the

battery/capacitor banks **130, 140**. A conventional braking system incorporated into the overall design may be greatly reduced in size since additional braking force can be provided by the transmission. Note that a mechanical braking system is not shown in any of the configurations but may be added if desired.

Four braking modes are available depending on the required braking force and state of charge of the battery/capacitor banks **130, 140**.

Braking - Maximum Regeneration:

For maximum regenerative braking, the generator input clutch **160** and generator output clutch **170** are engaged. The input **40** (engine) does not apply or absorb any power and, in fact, may be shut off. Both primary motor **24** and primary generator **22** function as generators charging the battery/capacitor banks **130/140**. Large amounts of kinetic energy are absorbed from the transmission output **26** until the battery/capacitor banks **130/140** are fully charged; braking ability in this mode is limited by the amount of energy that can be absorbed by the banks **130, 140**. At that point, either a conventional braking system or Full Engine braking (described below) must be used.

Maximum regenerative braking is used during short periods of high braking loads such as a panic stop in a vehicle or an emergency shut-off of a stationary machine.

Braking - Light Regeneration:

For light regenerative braking, none of the clutches are engaged. Energy is handled as described in Maximum Regeneration Mode above except that only the primary motor **24** functions as a generator. As described above, the battery/capacitor bank **130**, **140** capacity limits the amount of braking energy absorbed.

Light regeneration mode is used during short periods of low to medium braking alternating with "Economy Mode" in Forward or Reverse. An example would be a vehicle traveling in "stop and go" traffic.

Braking - Parallel:

In parallel braking mode, the mechanical drive clutch **90** is engaged, resulting in a power split between the engine input **40** and the electrical branch **20**. As a result, the kinetic energy absorbed from the transmission output **26**, can also be split. Part of energy can be converted as described above and stored by the battery/capacitor banks

130/140 and the balance is absorbed/dissipated by the engine (as in conventional engine braking).

Parallel mode is most suitable for, but not limited to, the situation in which braking energy to be absorbed/dissipated exceeds the storage capacity of the battery/capacitor banks **130**, **140**. An example of this would be controlling a heavy vehicle down an unusually steep grade.

Braking - Full Engine Mode:

In full engine braking mode, the lockup brake **80** is engaged in addition to mechanical drive clutch **90** and generator input clutch **160**. Kinetic energy is absorbed from the transmission output **26** and dissipated by the engine alone in the same fashion as conventional engine braking. This mode may be applied when the battery/capacitor bank **130**, **140** is full and maximum braking is required.

Engine Starting

As mentioned above, the duty cycle of the transmission may require cycling through the different modes many times. In order to realize maximum fuel economy the primary power

source (engine) should be shut off during modes where it is not required (full electrical and economy modes with regenerative braking). This is especially true if the primary power source happens to be an internal combustion engine. Of course, the primary power source will then need to be started or restarted to enter one of the other operating modes.

A conventional engine starter motor could be used but it has two major drawbacks: the engine cannot be started near its operating speed and the starter motor does not have the duty cycle required for the high frequency of engine restarts. By using the primary generator **22** as a starting motor for the engine, no extra components are added and the engine can be cranked near its required operating speed, which reduces emissions and increases fuel economy.

Starting - Output Stopped:

With the main output shaft **26** stopped, the generator input clutch **160** and split speed clutch **180** are engaged. The primary generator **22** functions as a motor, drawing stored energy from the battery/capacitor bank **130**, **140**. Since all other brakes and clutches are disengaged, the

primary generator **22** is able to turn the engine through the planetary gear set **10**, which has its elements locked together by the split speed clutch **180**. Once the engine is operating, the split speed clutch **180** is disengaged and any of the Forward/Reverse modes engaged.

Starting - Output in Motion

From a condition where the EMCVT is initially in one of the forward/reverse modes listed in table 1 where the engine is off and output shaft **26** is in motion, the generator input clutch **160** and split speed clutch **180** are engaged. The primary generator **22** operates as a starting motor for the engine. Once the engine is operating, the transmission is switched to one of the forward/reverse modes listed in **Figure 8** where the engine is on.

Alternatively, the EMCVT can operate in either Forward or Reverse Parallel mode and use the energy stored in the battery/capacitor bank **130**, **140** to maintain power to output shaft **26** as well as providing power to start the engine.

Optional Components

Geared Reverser:

As stated in the section "Reverse Operation", the full range of forward modes is not normally available in reverse. This suits most conventional vehicles and industrial applications where the performance demand for reverse operation is very low or not required at all. However, some applications may require all forward modes of operation (including all braking modes) in reverse. A simple solution to this problem is to install a geared reverser at either the input **40** or the output **26** of the EMCVT.

Placing a reverser **190** at the input **40** of the transmission as shown in **Figure 9** simply reverses the direction of all the components downstream of the input **40**. Since all speed and torque directions have been reversed, there is no negative power flow through any branch. The transmission will operate using any of the forward modes but with reverse output rotation.

An alternative (not shown) is to place the reverser **190** at the output **26**. The result is that the transmission components turn in one direction only regardless of final

output direction. The major drawback to an output reverser is the higher torque requirements placed on the reverser components compared to a reverser installed at the transmission input **40**. The resultant increase in size and weight makes the input reverser a better choice. Since the transmission serves to increase the torque available at the transmission input, a reverser installed at the output **26** must be much stronger than one installed at the input **40**. The resulting increase in weight and complexity would make an output reverser unsuitable for the majority of applications.

Range Splitter:

Due to the limitations of current generator/motor technology, a range splitter or doubler may be incorporated at the main output shaft **26** to increase the operating envelope of the transmission. **Figure 5** shows a parallel shaft EMCVT with a two-speed range splitter based on a planetary gear set **30** and a low-speed **32** and high-speed **34** clutch. The two-speed range splitter suits most applications although a three (or more) speed range splitter could also be incorporated if necessary.

Regenerative Steering System:

When the EMCVT is used to drive a tracked vehicle with two outputs, precise steering may be accomplished with a regenerative steering system as shown in **Figure 6**. If one output is required to turn slower than the other output, power is transferred from the slower side to the faster side rather than being bled off as heat as in a conventional brake-to steer system.

The steering generator **54** is driven either directly by or thru idlers by the input **40** of the transmission. When the power split is equal between outputs, the zero shaft **58** is prevented from turning by the steering motor **56** and the outputs of the steering planetaries **60** turn at the same speed. If more power is required to turn one output faster than the other, the steering motor **56** turns the zero shaft **58** in one direction or the other changing the relative speeds of the steering planetary **60** outputs.
Alternatively, the steering generator **54** may be omitted with power supplied to the steering motor **56** from the battery/capacitor banks **130/140**, the primary generator **22**, the primary motor **24** or a combination of these elements.

Another considerable advantage of the EMCVT lies in the ability of the configured systems as shown in **Figures 1** and **3** to enable a driven output on both ends of the transmission via a common output shaft **26**. This is particularly useful in vehicles or stationary equipment that require duplicated output shafts to two drives such as tracks and/or differentials. Furthermore, one or both of the outputs can be engaged or disengaged eliminating the need for a transfer case when configured for multiple output drives.

The EMCVT speed can be controlled in any conventional manner, however an electronic control system is preferred to best optimize the power splitting in connection with the output speed when operating in either forward or reverse Parallel mode. Furthermore, the electronic control system can also include control means for the optional range splitter and regenerative steering system as well as the various clutches and brakes discussed above.

Accordingly, while this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications of the illustrative

embodiments, as well as other embodiments of the invention, will be apparent to persons skilled in the art upon reference to this description. It is therefore contemplated that the appended claims will cover any such modifications or embodiments as fall within the scope of the invention.